Walch Hands-on Science Series

Our Solar System

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Contents

To the Teacher

This is one in a series of hands-on science activity books for middle school and early high school students. A recent national survey of middle school students conducted by the National Science Foundation (NSF) found that

- more than half listed science as their favorite subject.
- more than half wanted more hands-on activities.
- 90 percent stated the best way for them to learn science was to do experiments themselves.

The books in this series seek to capitalize on that NSF survey. The books are not texts but supplements, written by teachers. They offer hands-on, fun activities that will turn some students on to science. You and your students should select which activities are to be carried out. All of the activities need not be done. Pick and choose those activities that best meet the needs of your students. All of these activities can be done in school, and some can be done at home.

Students will need only basic, standard scientific equipment or household items that can be found in most middle and high school science laboratories or homes. The activities range from the simple (drawing ellipses to represent planetary orbits) to the difficult (observing the Sun). There is something for every student.

THE ACTIVITIES CAN BE USED:

- to provide hands-on experiences pertaining to textbook content.
- to reinforce key scientific principles through direct experience.
- to give verbally limited children a chance to succeed and gain extra credit.
- as the basis for class or school science fair projects or for other science competitions.
- to involve students in science club undertakings.
- as homework assignments.
- to involve parents in their child's science education and experiences.
- to foster an appreciation of the solar system and our place in it.

Students can learn important scientific principles from carrying out these activities. For example:

- The planets move in predictable paths governed by physical laws.
- Many geological features such as impact craters and volcanoes are not unique to Earth, but are found through much of the solar system.
- The compositions of the planets are a result of the way in which the solar system formed.

Each activity has a Teacher Resource section that includes, besides helpful hints and suggestions, a scoring rubric, quiz questions, and Internet connections for those students who wish to go further and carry out the follow-up activities. Instructional objectives and the National Science Standards that apply to each activity are provided to help you meet state and local expectations.

Kepler's Second Law: How Do Planets Move?

TEACHER RESOURCE PAGE

INSTRUCTIONAL OBJECTIVES

Students will be able to

- state Kepler's Second Law.
- describe how a planet changes speed as it moves in an elliptical orbit.

NATIONAL SCIENCE STANDARDS ADDRESSED

Students demonstrate an understanding of

- predictable motion of the planets.

Students demonstrate scientific inquiry and problem-solving skills by

- identifying variables in experimental and non-experimental settings.
- working in groups to collect and share information and ideas.

Students demonstrate effective scientific communication by

- representing data in multiple ways.
- arguing from evidence and data.

MATERIALS

For each pair of students:

- Pen or pencil
- Calculator
- Protractor
- Ruler
- Access to a photocopier

HELPFUL HINTS AND DISCUSSION

Time frame: 40 minutes, or a single period
Structure: In pairs
Location: In class

It would be helpful for the students to do the activity on Kepler's First Law before they do this activity. That way, they would already be familiar with the concept that planetary orbits are ellipses, and they will have had a chance to draw and examine ellipses.

The procedure calls for both students in a pair to work together to draw the sectors of the orbit on Figure 2, but then to count squares and measure arcs separately working from photocopies of their work in steps 1–4. If a photocopier is not available for this purpose, have the students in a pair each work on their own copy of Figure 2, helping each other through steps 1–4 but working separately on the remainder of the activity.

ADAPTATIONS FOR HIGH AND LOW ACHIEVERS

High Achievers: Encourage these students to do the Extensions and Follow-up Activities.

Low Achievers: Review Kepler's First Law with these students and have reference materials available. Review the use of a protractor. These students can be paired with high achievers for this activity.

SCORING RUBRIC

Full credit can be given to students who conclude correctly that the two areas are the same, and that the planet moves faster when it is close to the Sun. Extra credit can be awarded to students who do the Extensions or any of the Follow-up Activities. The quiz can be scored from 1 to 4 correct.

INTERNET TIE-INS

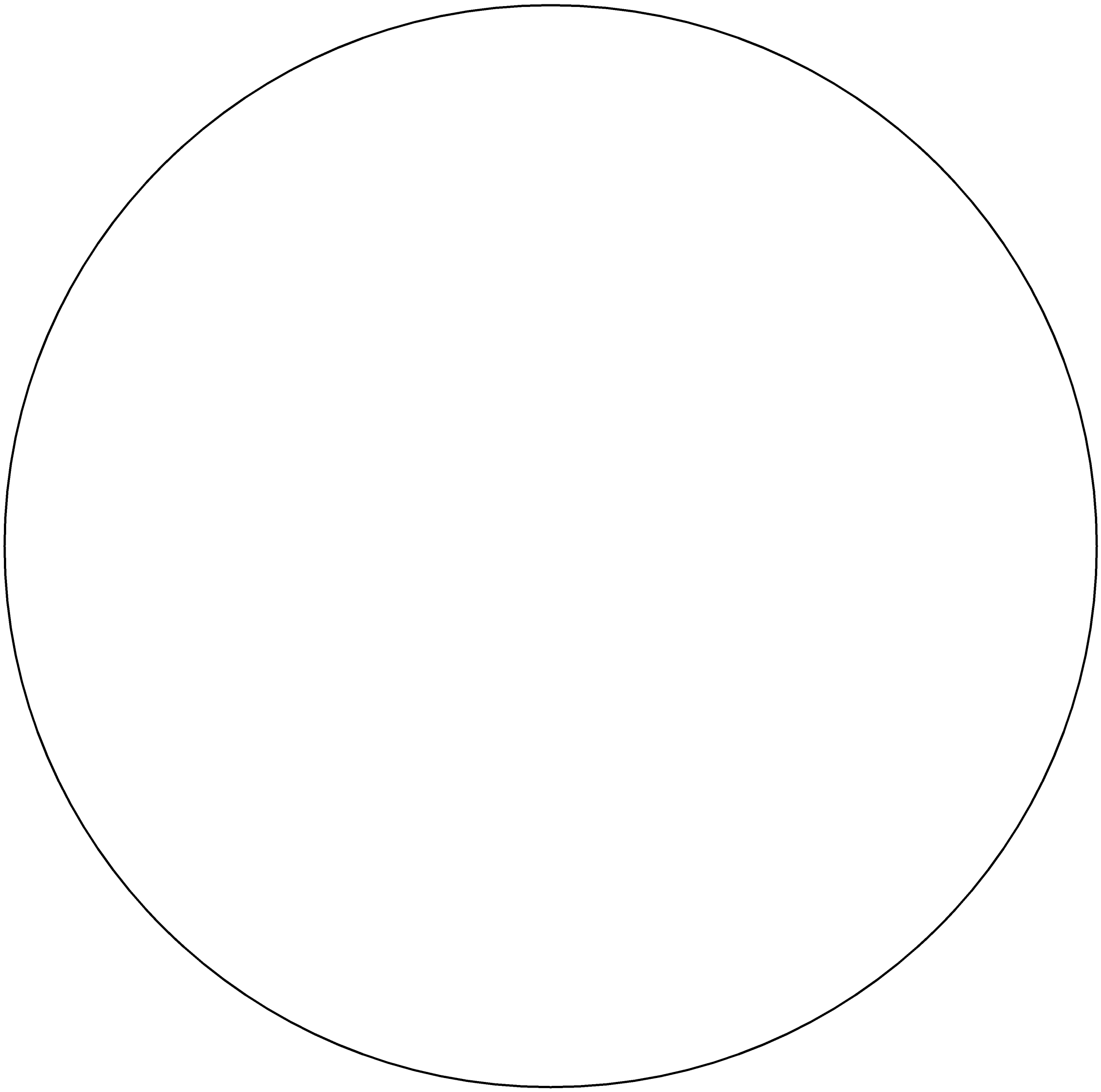
http://windows.ivv.nasa.gov/the_universe/uts/kepler2.html

QUIZ

1. State Kepler's Second Law in one sentence.
2. Does a planet move faster in its orbit when it is near the Sun or when it is farther from the Sun?
3. During what month is the Earth closest to the Sun, and during what month is it farthest from the Sun?
4. When does the Earth travel fastest in its orbit and when does it travel slowest?

Name ______________________________ Date ____________________

Figure 3



Name ______________________________ Date ____________________

Kepler's Second Law: How Do Planets Move?

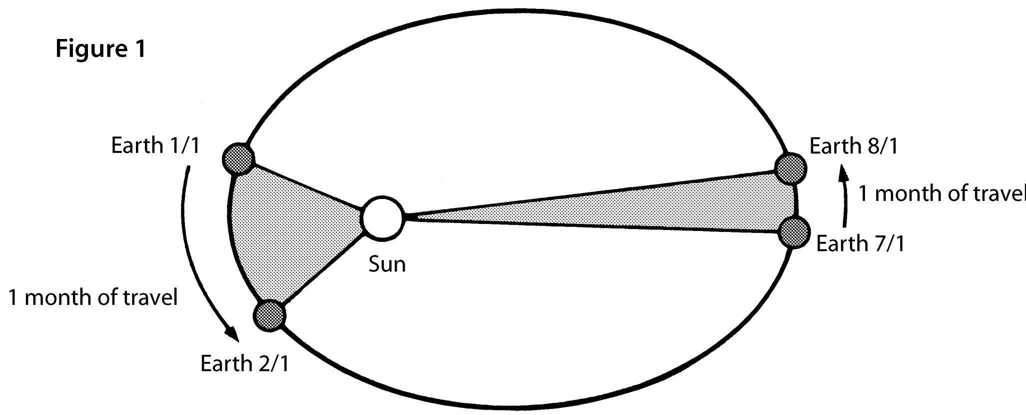
STUDENT ACTIVITY PAGE

BEFORE YOU BEGIN

Johannes Kepler (1571–1630) discovered three rules that govern how planets orbit the Sun. These rules are called Kepler's Laws. The first of these laws describes the shape of a planetary orbit as an ellipse, with the Sun at one focus of the ellipse. In this activity you will examine Kepler's Second Law, which describes how a planet changes speed as it moves in its orbit.

Kepler's Second Law states that a line connecting the Sun and any planet sweeps out equal areas in a given length of time (say, one month). That is true regardless of where the planet is in its orbit or how far it is from the Sun at that time. As shown in Figure 1, the two shaded areas are equal. For this to be true, the planet must move faster when it is closer to the Sun, in order to cover a greater distance along its orbit, than when it is farther from the Sun. For example, the Earth is closest to the Sun in January, and farthest in July. So the Earth must move faster in its orbit in January than in July.

Figure 1



MATERIALS

- Pen or pencil
- Calculator
- Protractor
- Ruler
- Access to a photocopier

PROCEDURE

Share the tasks in steps 1–5 with your partner. Each of you should do steps 6–8 separately and enter your answers in the Data Collection and Analysis section.

Figure 2 shows an ellipse with the Sun's position at one focus. This ellipse is only for demonstration. Real planetary orbits in our solar system are much closer to circles. The major axis (the longest dimension) of the ellipse is drawn in for you. Remember that the Sun lies on the major axis. You will draw in two sectors, representing equal intervals of time during a planet's orbit around the Sun.

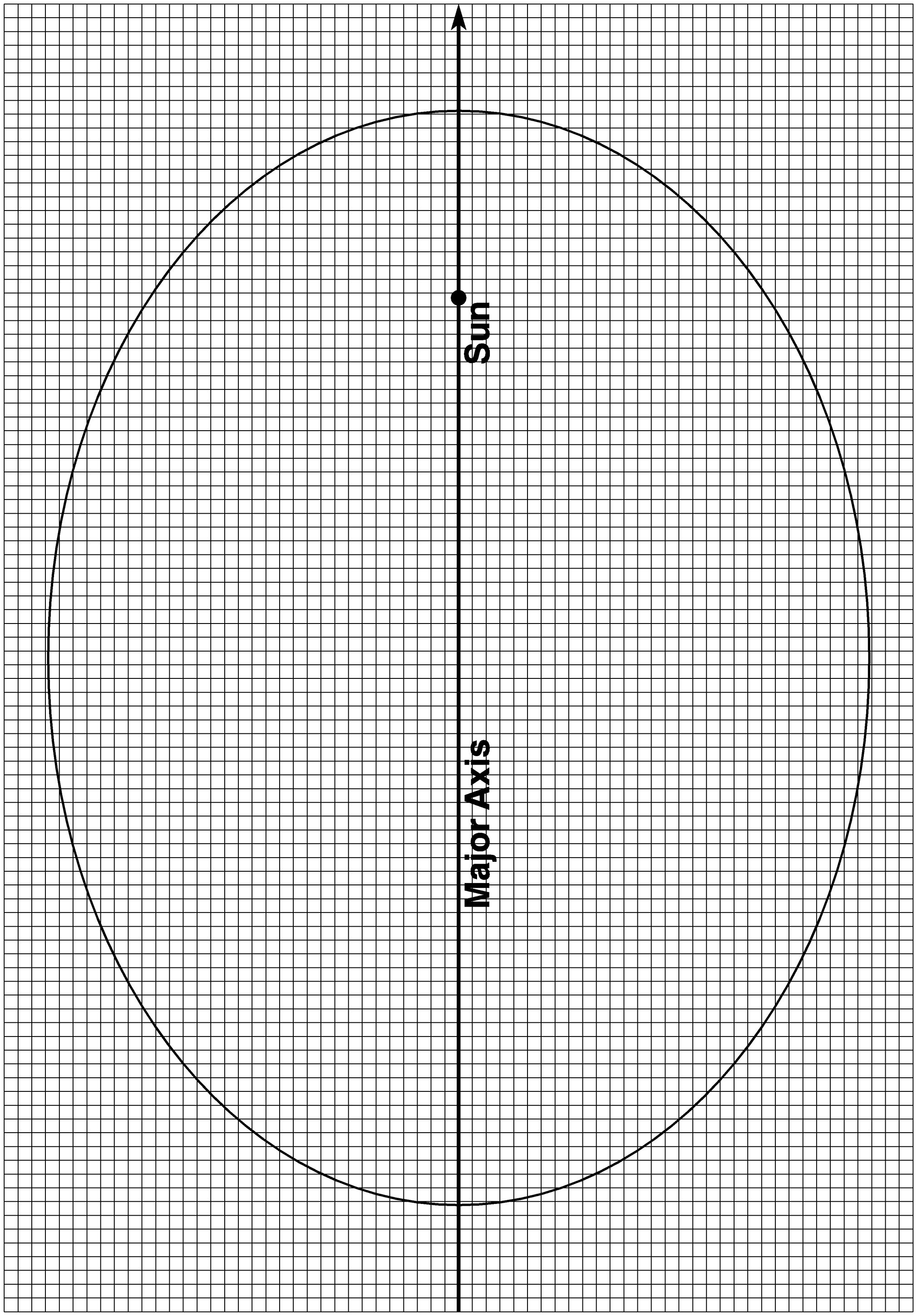
(continued)

Name ______________________ Date ______________________

Kepler's Second Law: How Do Planets Move? *(continued)*

STUDENT ACTIVITY PAGE

Figure 2



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Name ______________________________ Date ______________

Kepler's Second Law: How Do Planets Move? *(continued)*

STUDENT ACTIVITY PAGE

1. Hold Figure 2 so that the arrow on the major axis points up. Line up the protractor with its center on the Sun and the 90° mark along the major axis, pointing in the direction of the arrow. Mark an angle that is 53° to either side of the 90° direction. That is, make marks at 37° and 143°.
2. Use the ruler to draw two straight lines extending from the Sun to the ellipse along each of the angle marks you just made. Label the area enclosed by these two lines and the arc segment of the ellipse as Sector A.
3. Now, turn the paper so that the arrow points down. Line up the protractor with its center on the Sun and the 90° mark along the major axis, pointing away from the arrow. Mark an angle that is 5° clockwise from the 90° mark.
4. Use the ruler to draw a straight line extending from the Sun to the ellipse along the angle mark you just made. Label the area enclosed by the line you just made, the major axis, and the arc segment of the ellipse, as Sector B.
5. With the sectors drawn and labeled, make two photocopies of Figure 2 so that each of you can do steps 6–8 independently.
6. Count the squares in each of the two sectors you just drew. It may be convenient to first count the complete squares, and then add the areas of the partial squares. For partial squares, estimate to the nearest $\frac{1}{4}$ square. Enter your values for the total area of each sector in the Data Collection and Analysis section.
7. Measure the length of the arc segment of the ellipse for each of the two sectors. Since these lines are curved, you cannot do this directly with the ruler. Try "rolling" the ruler along the curve from one end of the arc segment to the other. Another method is to break the arc segment into a number of small pieces (say, less than a centimeter long each) and then measure and add up the lengths of these pieces. You could also lay a piece of string along the arc and then measure the string. Record your results in the Data Collection and Analysis section.
8. Calculate the ratio of the length of the arc segment in Sector A to that of Sector B. Record your results in the Data Collection and Analysis section.

EXTENSION

Draw in a third sector, Sector C. With the arrow pointing to the right, line up the protractor with the center of the protractor on the Sun and the 0° mark along the major axis. Mark an angle at 90° (straight up). Mark another angle that is 30° counterclockwise from the 90° direction. Draw the lines to make a sector, and measure the area and arc segment length of the sector.

(continued)

Name ______________________________ Date ____________________

Kepler's Second Law: How Do Planets Move? *(continued)*

STUDENT ACTIVITY PAGE

DATA COLLECTION AND ANALYSIS

Area of Sector A __________ squares
Area of Sector B __________ squares
Length of Sector A arc __________ millimeters
Length of Sector B arc __________ millimeters
Ratio of arc A to arc B __________

EXTENSION

Area of Sector C __________ squares
Length of Sector C arc __________ millimeters

CONCLUDING QUESTIONS

1. Are the areas of Sectors A and B equal or unequal? (Consider them equal if your measurements are the same to within 10% of each other, unequal otherwise.)

 ____

2. What is the ratio of the length of arc A to arc B? ______________________

 What do your results imply about the speed of a planet as it orbits the Sun? (Remember, Sectors A and B represent equal time intervals.) ______________________

 ____

3. If a planet had a perfectly circular orbit, how would its speed behave as it moved along in its orbit?

 ____

EXTENSION

Does Sector C represent the same time interval as Sectors A and B? Explain your answer.

Follow-up Activities

1. The planet whose positions led Kepler to conclude that orbits were ellipses was Mars. Figure 3 is an accurate representation of the shape of Mars' orbit. Obtain a copy of Figure 3 from your teacher. Do not add any labels or description. Show it to friends and family, and ask them to identify what geometric shape it is. Show as a bar graph how many people say it is a circle and how many say it is an ellipse (or oval). What do you think of Kepler's ability to determine the difference? Present your results to your class.
2. There are several interactive orbit simulators on the Internet, including http://www.explorescience.com/orbit.htm. There are also a number of freeware and shareware planetary motion simulators for Windows and Macintosh personal computers. Find and obtain access to one or more of these and spend some time examining the real orbits of planets, asteroids, and comets. Also make up your own orbits for hypothetical solar system objects. Some keywords to use in your search are *Kepler, orrery, planet, orbit,* and *simulator.*